



# Xinetics Inc.

Government Tech Days

UAH

September 16 / 18

2003



# Silicon Carbide Agile Manufacturing

- Physical Properties
- Manufactured Forms
- Manufacturing Processes
- Processing Requirements
- Xinetics' Solution

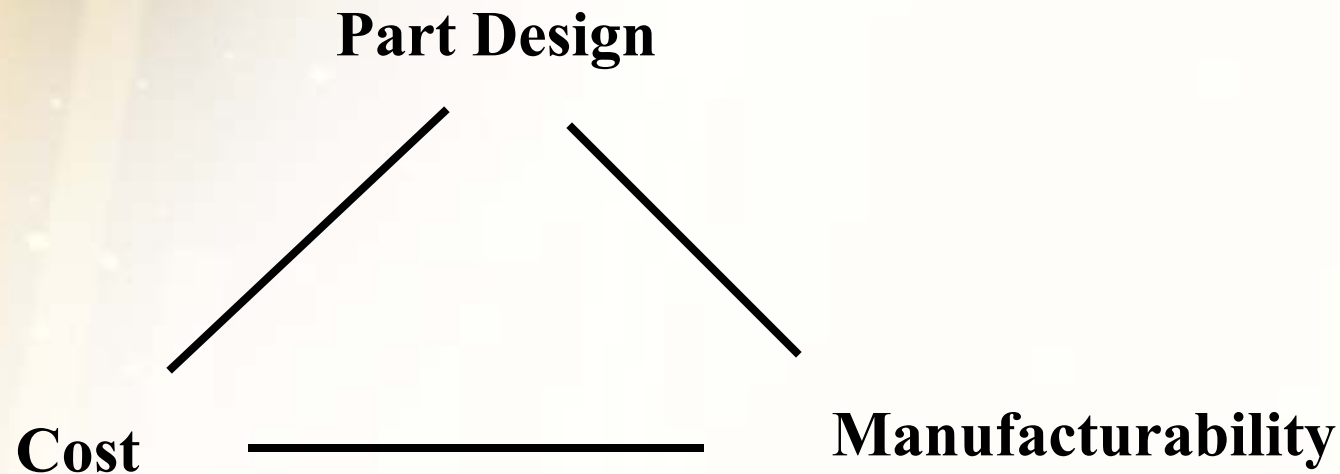


# Silicon Carbide – the material

- Physical Properties
  - Low CTE
  - High thermal conductivity
  - Low specific gravity
  - High hardness
  - High elastic modulus
  - Semiconductor
- Two forms
  - Beta – Low temperature, cubic
  - Alpha – High Temperature, Hex w/numerous polytypes



# Silicon Carbide - Requirements



Silicon Carbide isn't a "thing" it's a material –  
We need to manufacture a "thing" out of it



# Silicon Carbide Manufactured Forms (Optics)

- CVD – Zero porosity, beta phase
  - Coatings or thin simple monolithic pieces
- Hot Pressed – Zero Porosity, alpha phase
  - Monolithic blocks or simple geometries
  - Diamond ground shapes
- Sintered – Porous alpha, or beta, or mixture
  - Variety of sizes and shapes, thin components tend to be of simple geometry
- Reaction Bonded – In proper form - 2 phase mixture of Si and SiC, but often contains other phases such as carbon
  - Wide variety of sizes and shapes determined by mfg process
  - Starting material – SiC, SiC/C, Carbon fiber preforms, Graphite



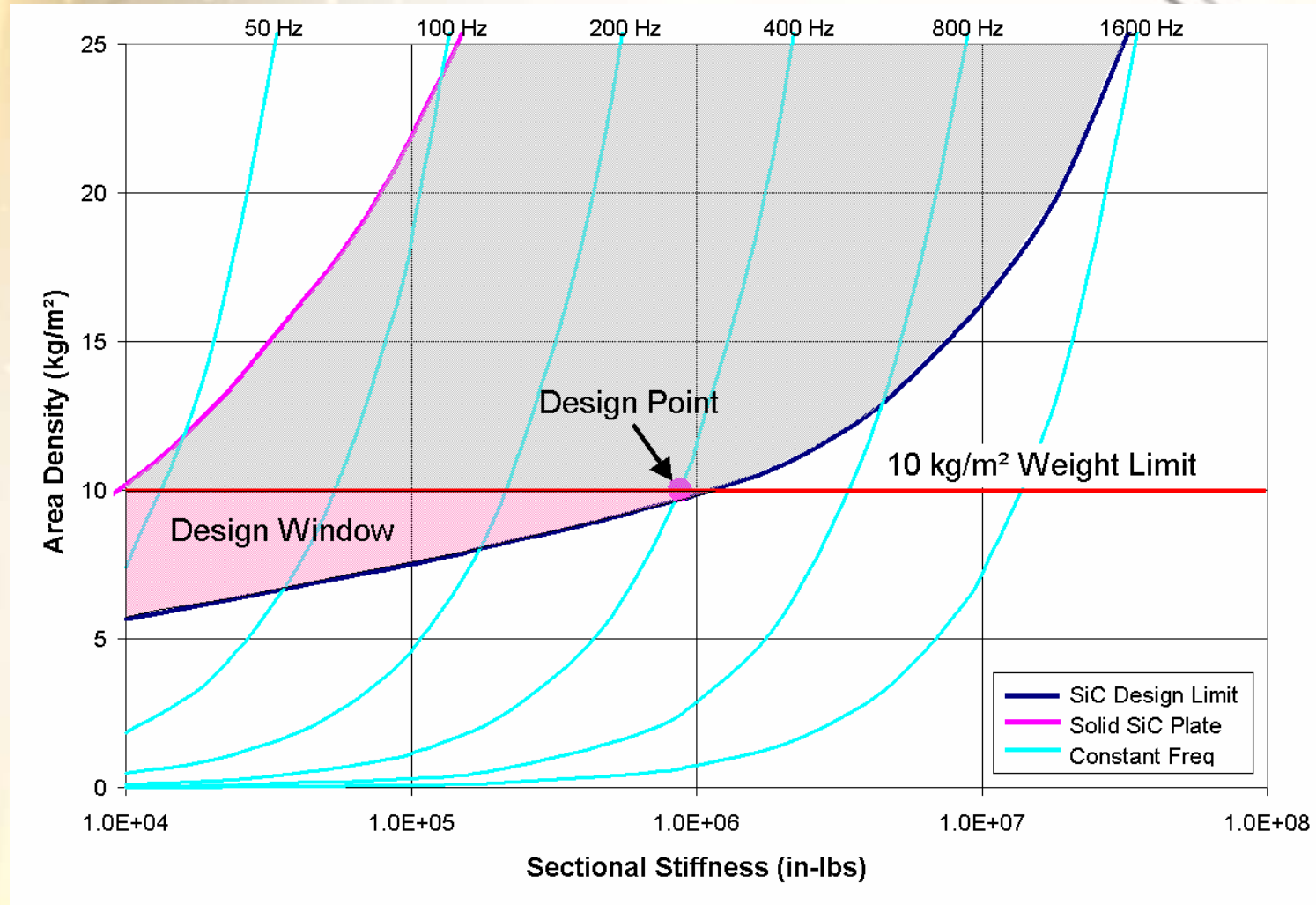
# Silicon Carbide – Forming processes for Manufactured Types

- Sintered and Reaction Bonded SiC – forming can be done in variety of ways and is separate from firing
- Forming - Depends on size, shape and complexity
  - Pressing
  - Automatic dry pressing –
  - Vacuum forming
  - Extrusion
  - Injection molding –
  - Casting –
  - Forming and Green Machining –



# Lightweight Mirror Structural Trades

Determine optimal stiffness to weight performance

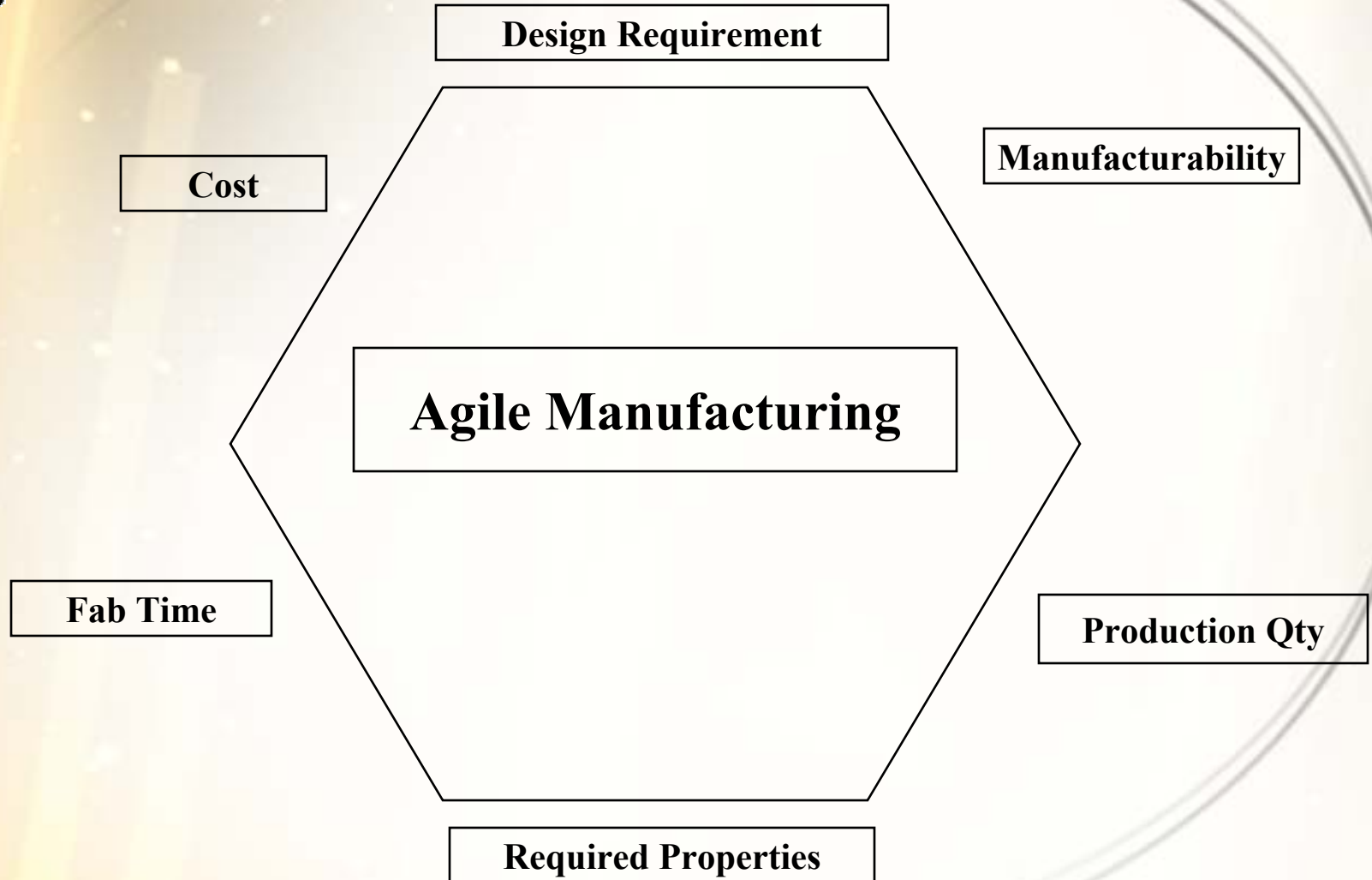


(Frequencies based on a 1.0m HEX Free-Free)





# Manufacturing Requirements

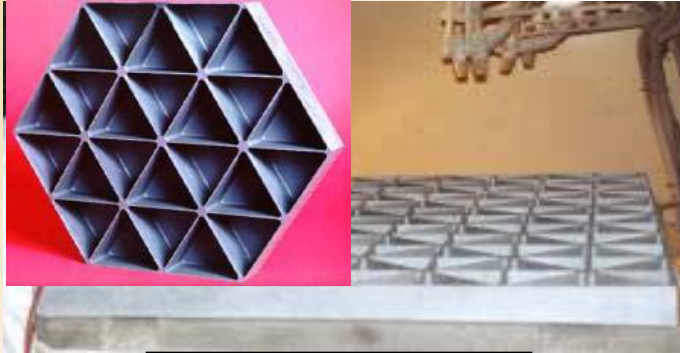




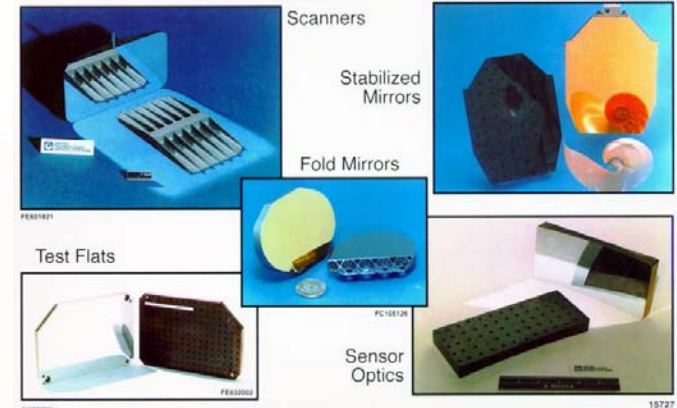


# Silicon Carbide Optics and Structures

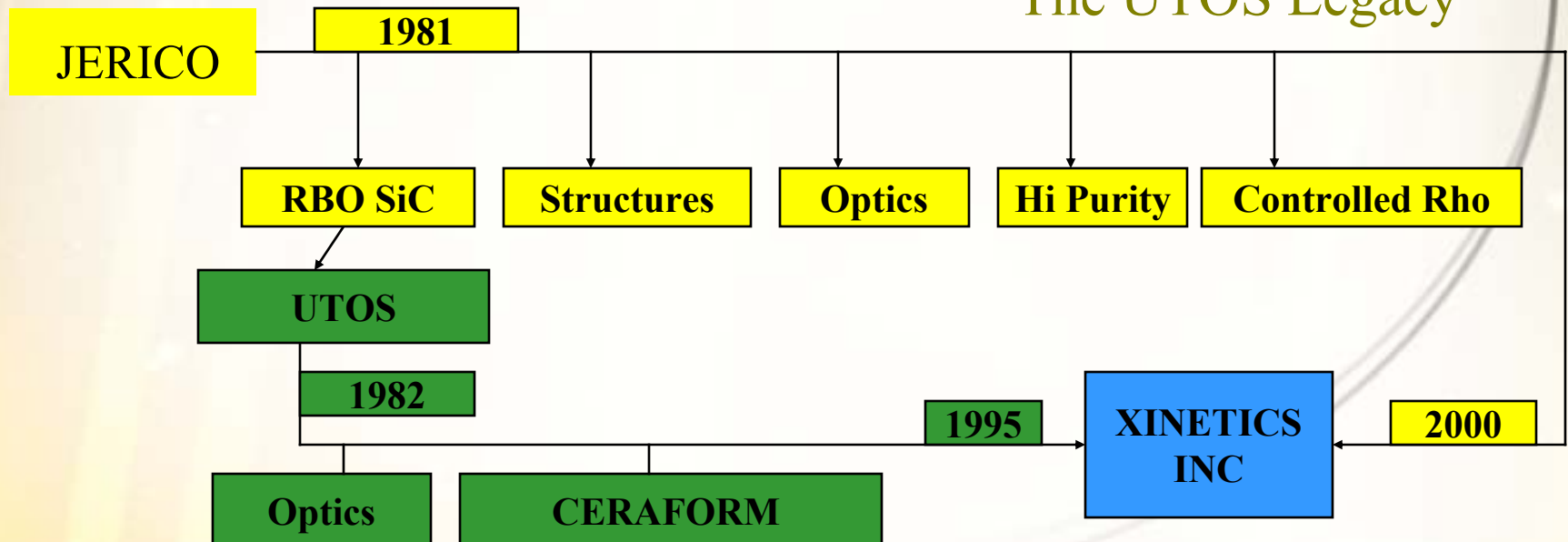
... Xinetics Purchases UTOS Technology in 1995 and Jerico in 2000



The Jerico Legacy



The UTOS Legacy



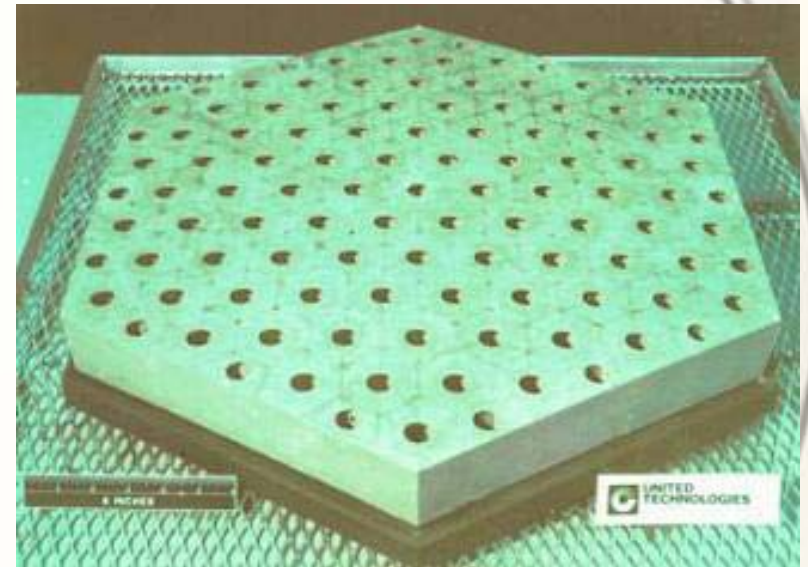
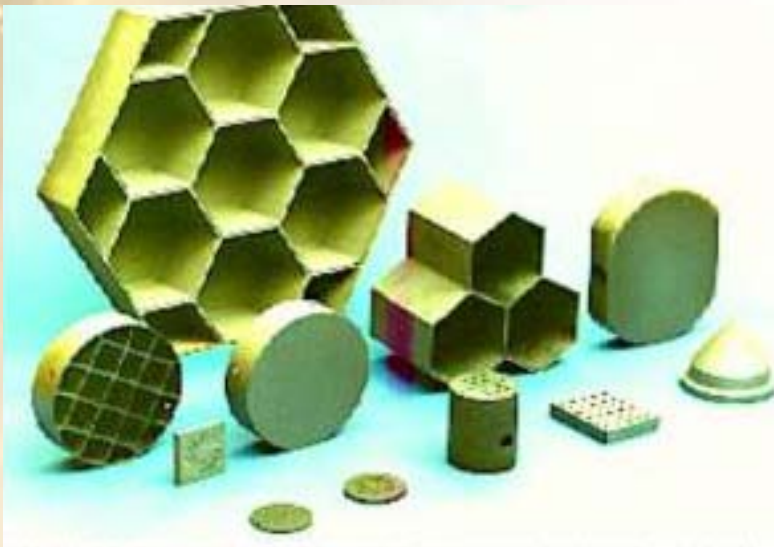


# Silicon Carbide - Agile Manufacturing

- Ability to make wide variety of shapes
- Ability to achieve required properties
- Ability to manufacture new designs quickly
- Ability to do production volumes
- Ability to do all this cost effectively
  
- METER CLASS ASPHERES
- FAST MIRRORS FAST



# Xinetics has legacy in SiC going back to 1980



**\* Fugitive Core Enables Near Net Shape, Monolithic Construction**



# Xinetics has legacy in SiC going back to 1980



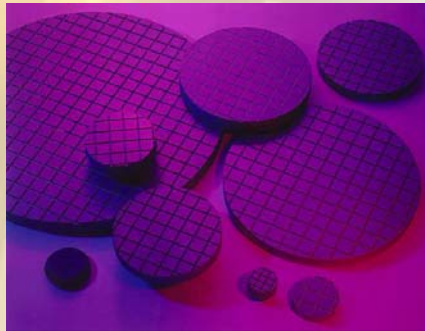
**\* Engineered Microstructure Enables Direct Silicon Carbide Polishing**





# Silicon Carbide Optical Structures

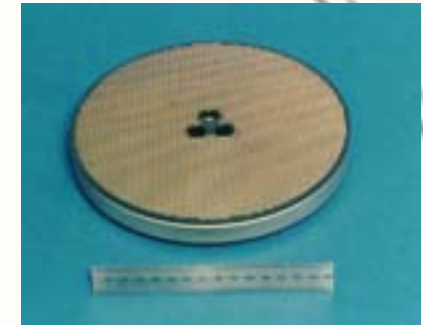
## ... Near Net Shape with Integral Interface Features



**Small & Large SiC  
Polishing Laps**



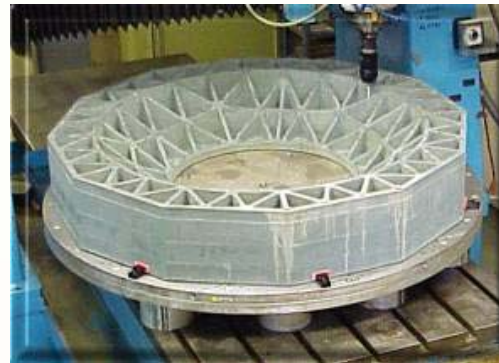
**15-cm All Silicon Carbide  
Telescope Structure**



**300-mm Silicon Carbide  
Vacuum Chuck**



**37-Inch IFX RCIS  
First Article**



**52-Inch ALPHA BCIS  
First Article**



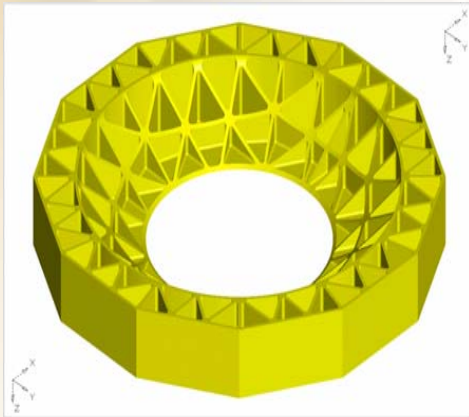
**36-Inch ALPHA BCIS  
First Article**



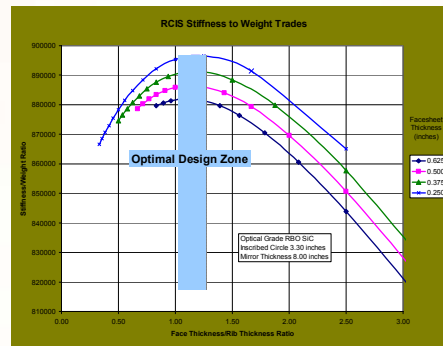
# BMDO ALPHA BCIS Bottom Structure

## ... Demonstrates Optical Structures to 52-Inches

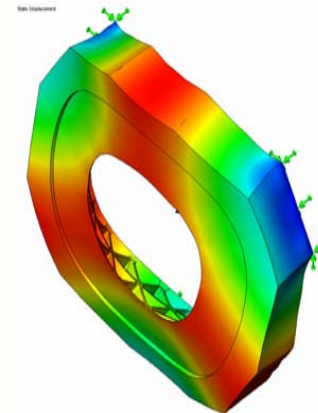
Design Concept



Design Trades



Detailed Analysis



Mold Design



Pathfinder Fabrication



21 inch Diameter

Finished Part



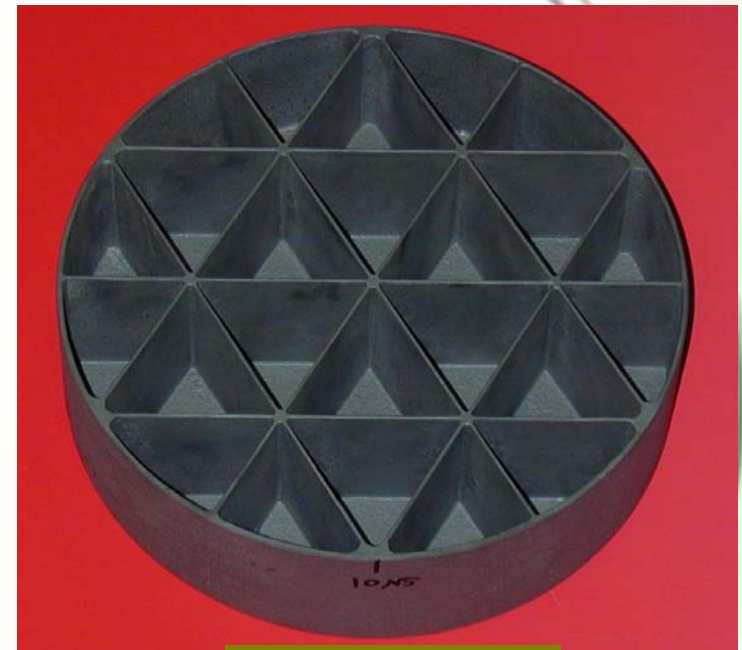
52 inch Diameter, 350 lbs



# Polishing Study

## 8 Inch Diameter Mirrors

- Design Approach
  - 8" diameter
  - 2.112 overall thickness
  - 0.093 face thickness
  - 0.067 web thickness
  - 1.334 cell diameter
  - Open back
- Evaluate polish of lightweight SiC ( $\sim 20\text{kg/m}^2$ ) and transfer lessons learned to 0.5m mirror design.



8 inch SiC Mirror

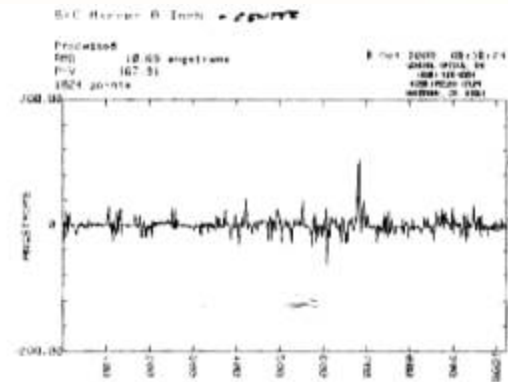




# Wave Precision – 8 –Inch Dia Bare SiC Polish

... Figure =  $\lambda/33$  PV, Roughness = 11 Å rms; Cost = \$1500.

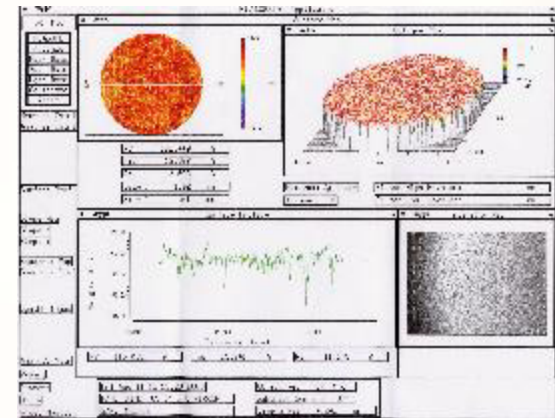
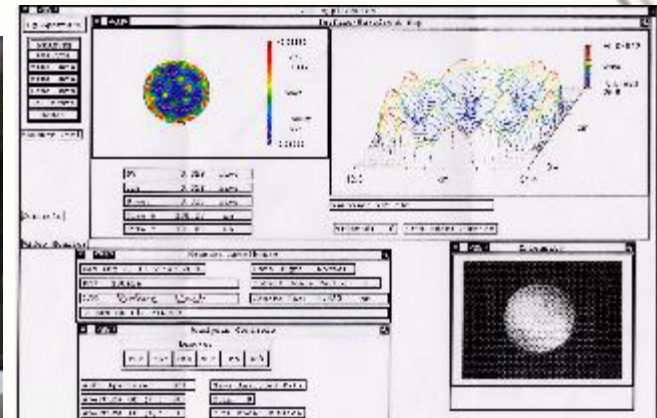
8" Diameter \$1500





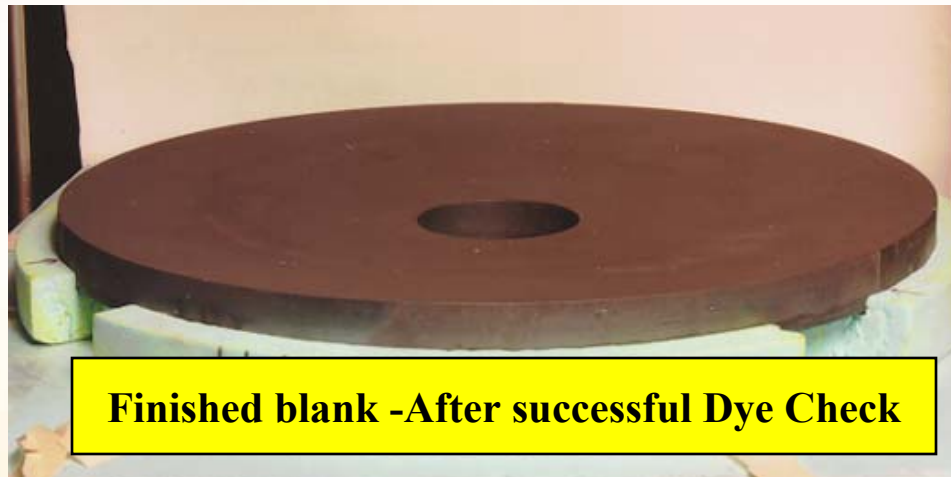
# Zygo DOP – 8-Inch Dia Bare SiC Polish

... Figure =  $\lambda/17$  PV, Roughness = 11 Å rms; Cost = \$7650.





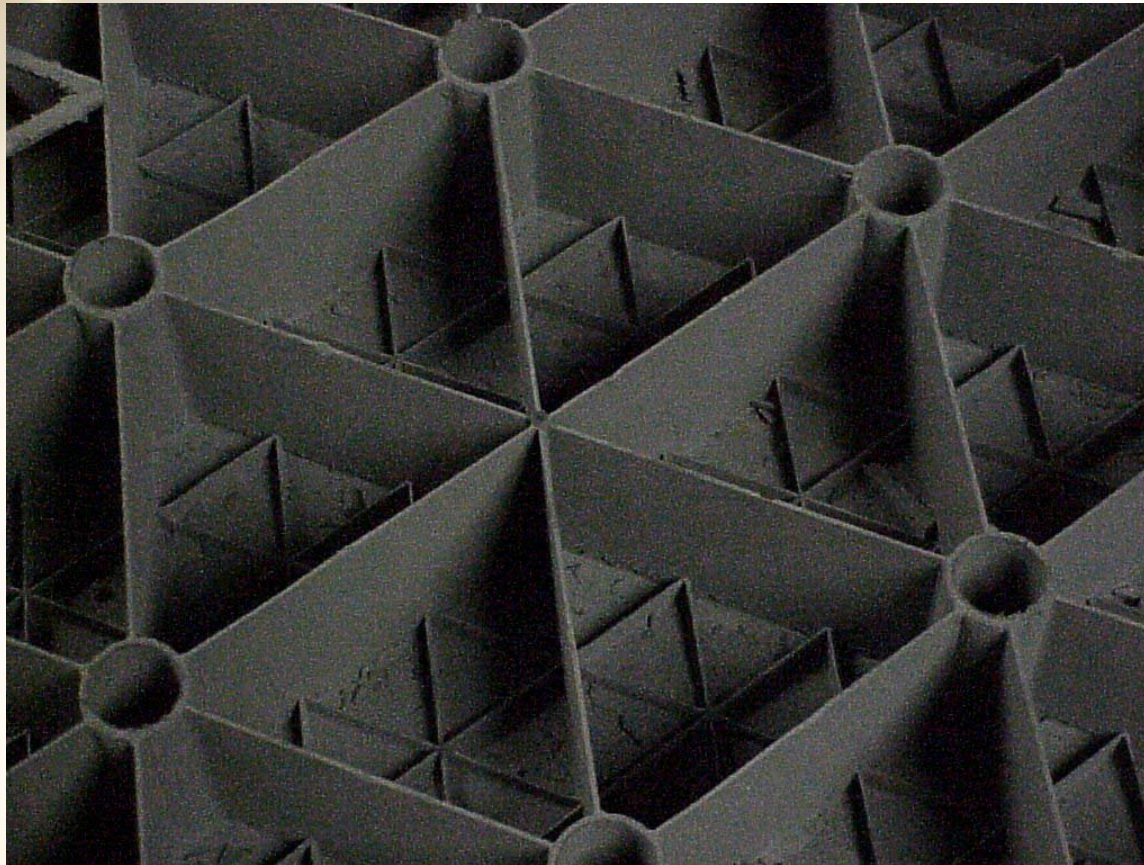
# 1 Meter CERAFORM lightweight SiC







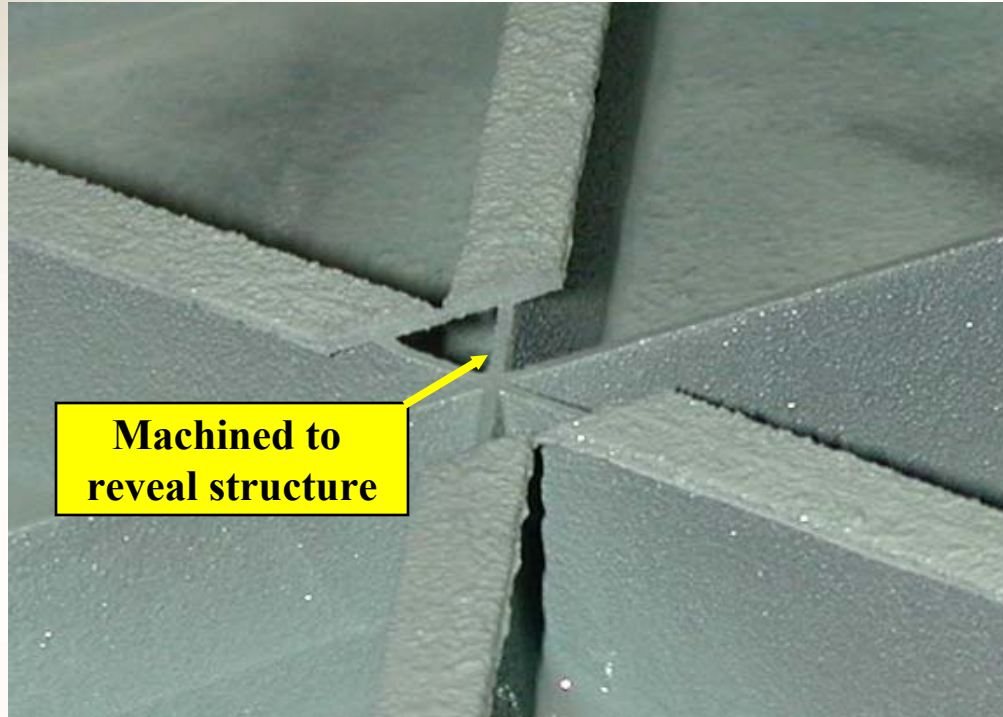
# Zonal Meniscus 40 cm Hex Mold Type 2 - As Prefired



**Xinetics Proprietary Information**



40 cm part with 0.020 walls  
near net shape as pre-fired



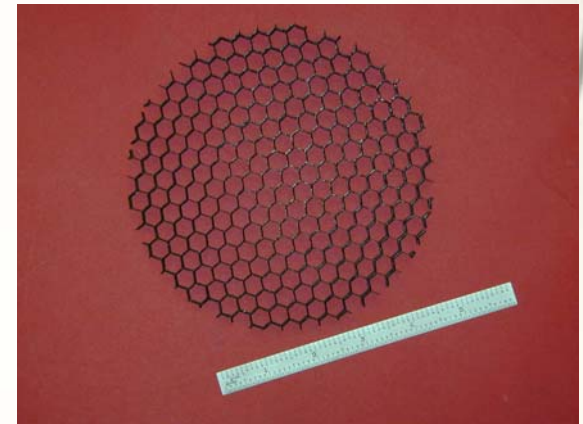
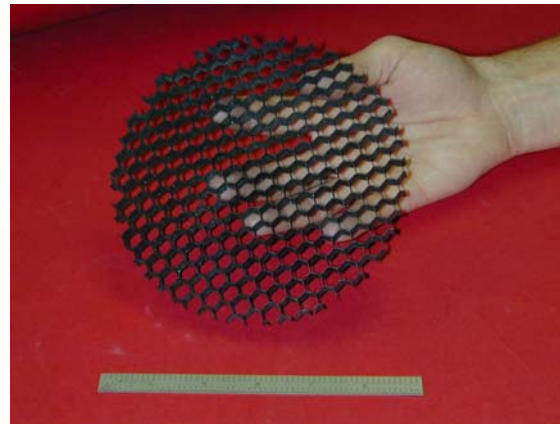
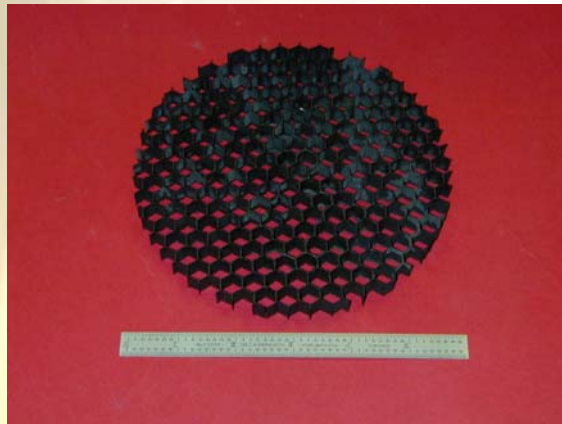
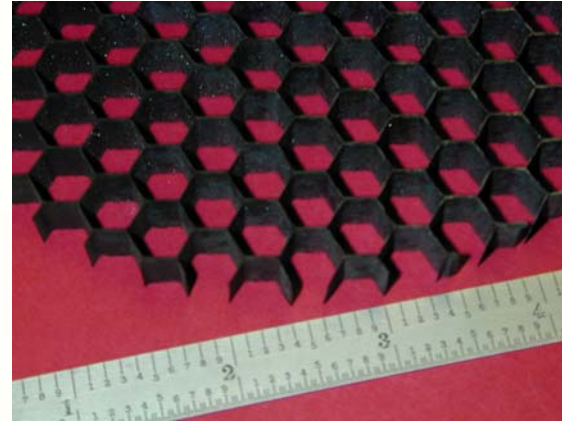
**Machined to  
reveal structure**





# Advanced Materials for Lightweight Space Based Mirrors

- CERACORE SiC core
- 0.375 cells / 0.009 walls





# Silicon Carbide - Agile Manufacturing Meter Class Optics

- Ability to make wide variety of shapes
  - Off-axis aspheres
- Ability to achieve required properties
  - Reaction bonded silicon carbide
- Ability to manufacture new designs quickly
  - Less than 6 months from print to part
- Ability to do production volumes
  - Greater than one part per week
- Ability to do all this cost effectively
  
- FAST MIRRORS FAST





# Silicon Carbide - Agile Manufacturing considerations

- Ability to make wide variety of shapes
- Variety of designs – open, closed, semiclosed
- Range of areal densities
  - Not difficult to make lightweight
  - Difficult to make lightweight and stiff
- PRODUCTION TECHNIQUES NOT MATERIALS PROPERTIES GENERALLY DEFINE LIMITS OF THE WEIGHT / STIFFNESS OF PARTS THAT CAN BE MANUFACTURED

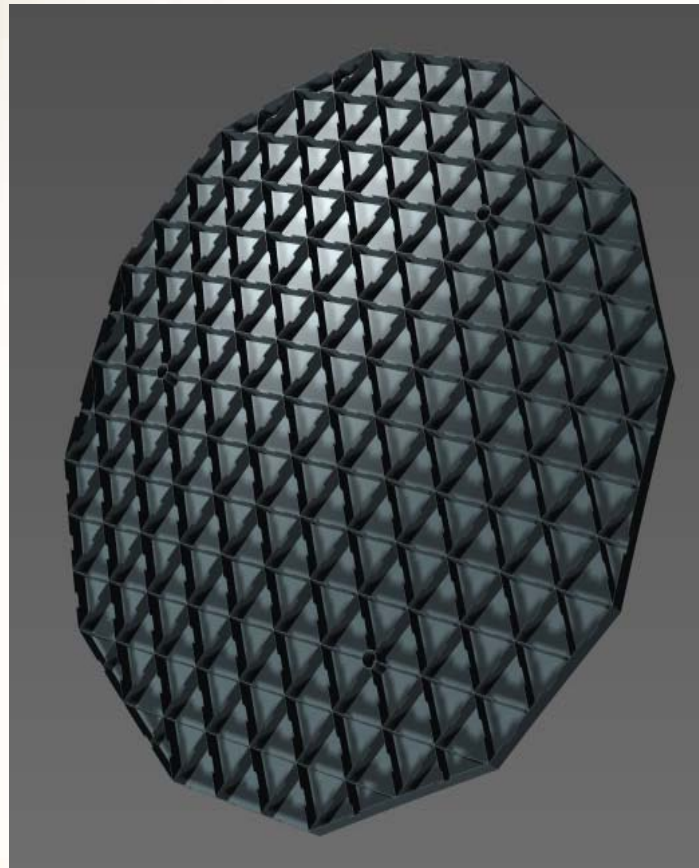


# Silicon Carbide - Agile Manufacturing Meter Class Optics

- Utilize a modified molding / casting process that combines standardized mold components with mold “fillers” that can be quickly and inexpensively made or modified to produce the desired component.
- To this process a 1 meter open back flat mirror at 30 Kg/m<sup>2</sup> and a 1.2 meter closed back off axis asphere at 15 Kg/m<sup>2</sup> look very similar
- FAST MIRRORS FAST

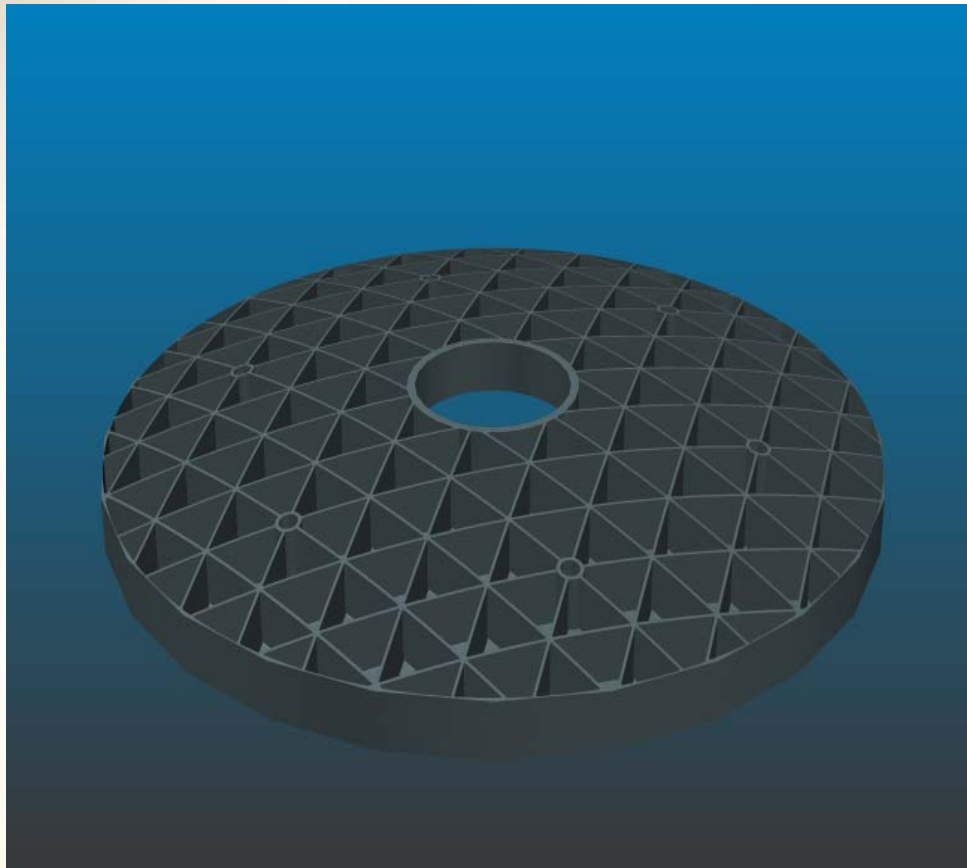


75 cm on axis asphere



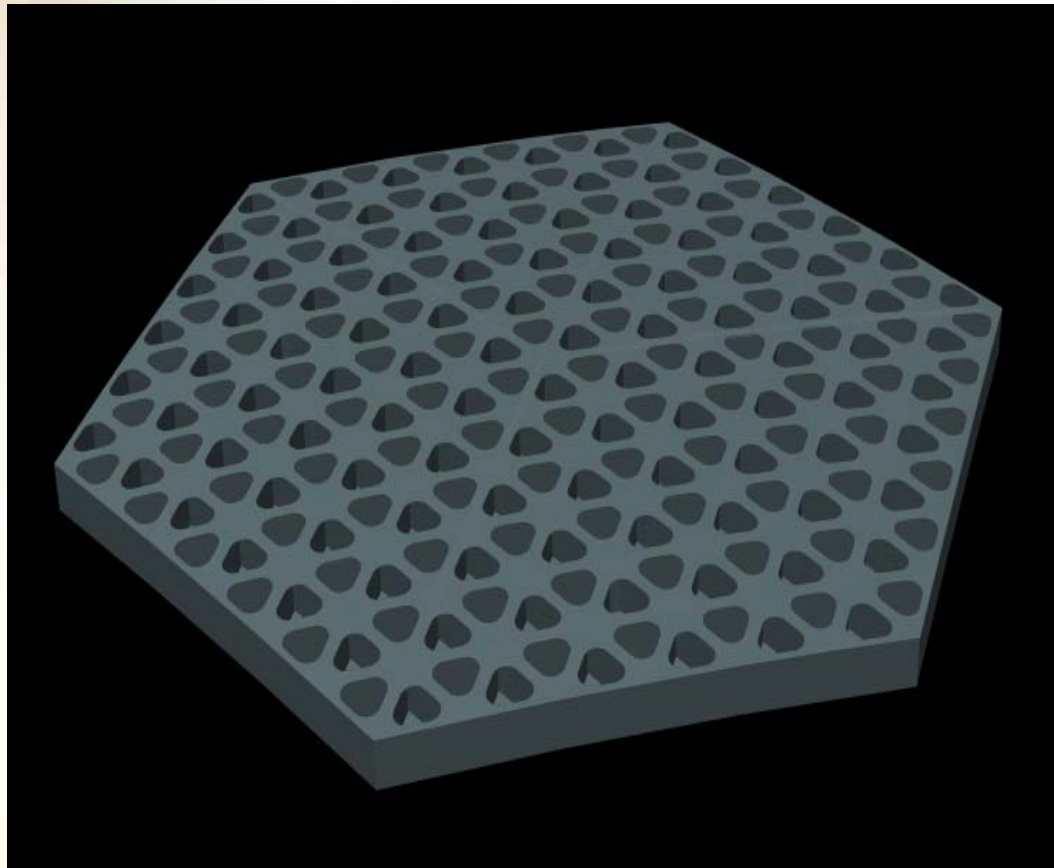


1.1 meter on axis sphere with  
~ 2 meter roc





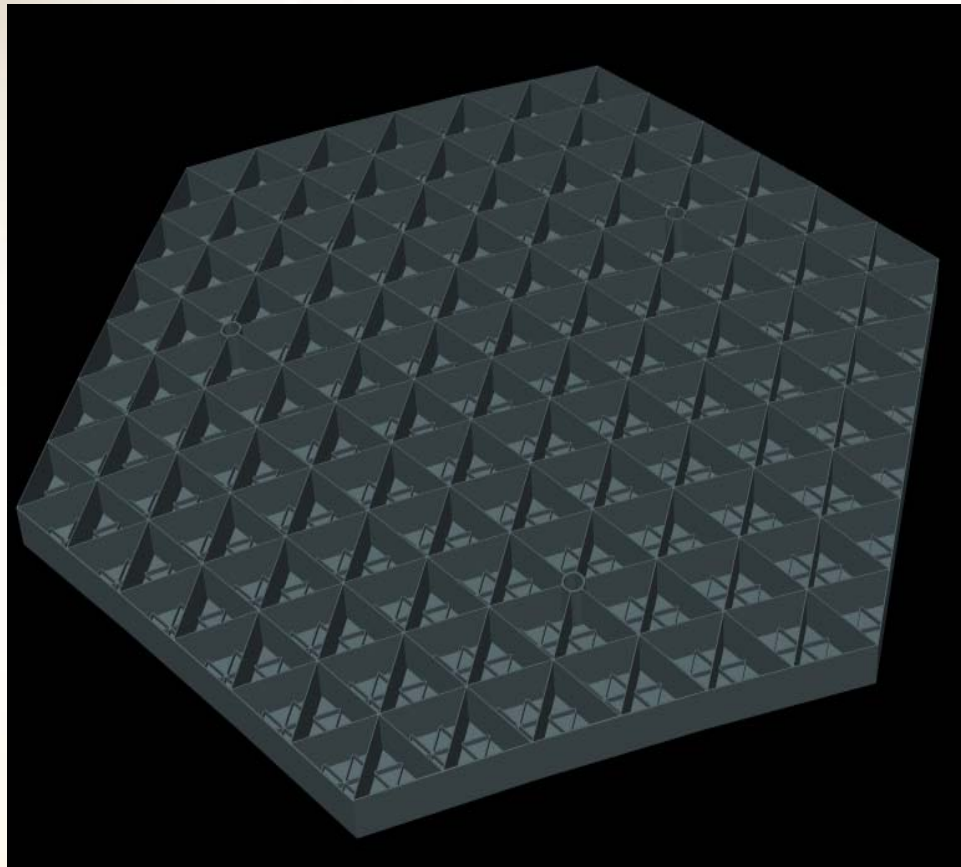
1 meter semi-closed back - sphere





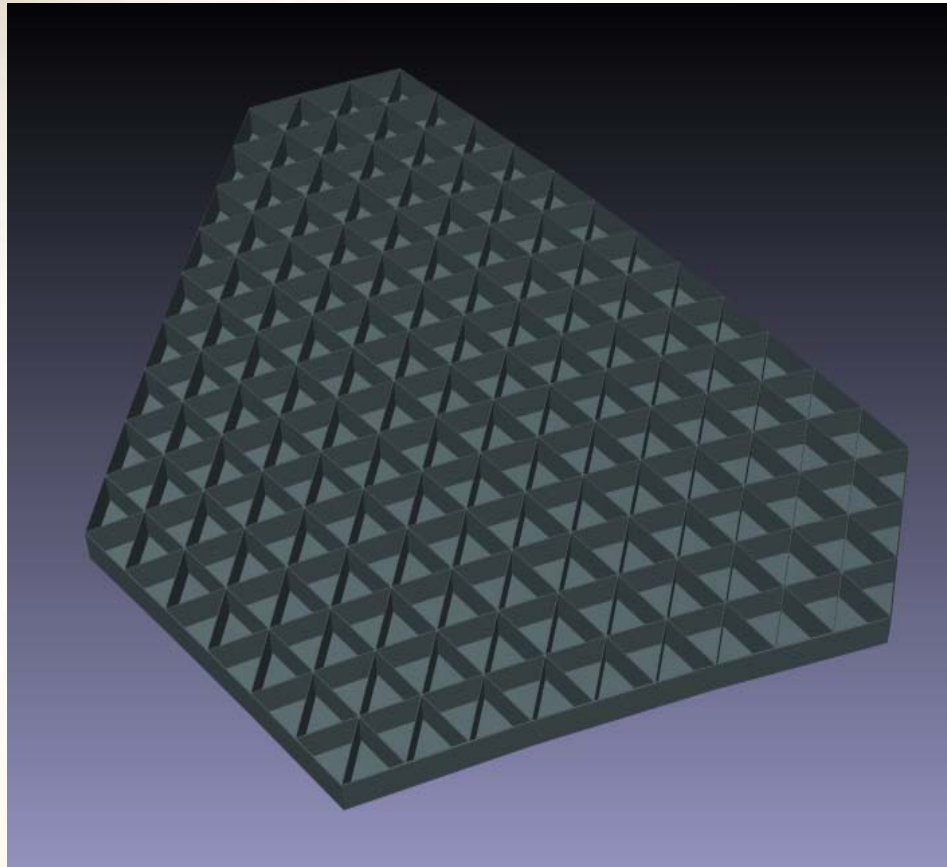


1 Meter open back sphere – center  
segment of larger mirror





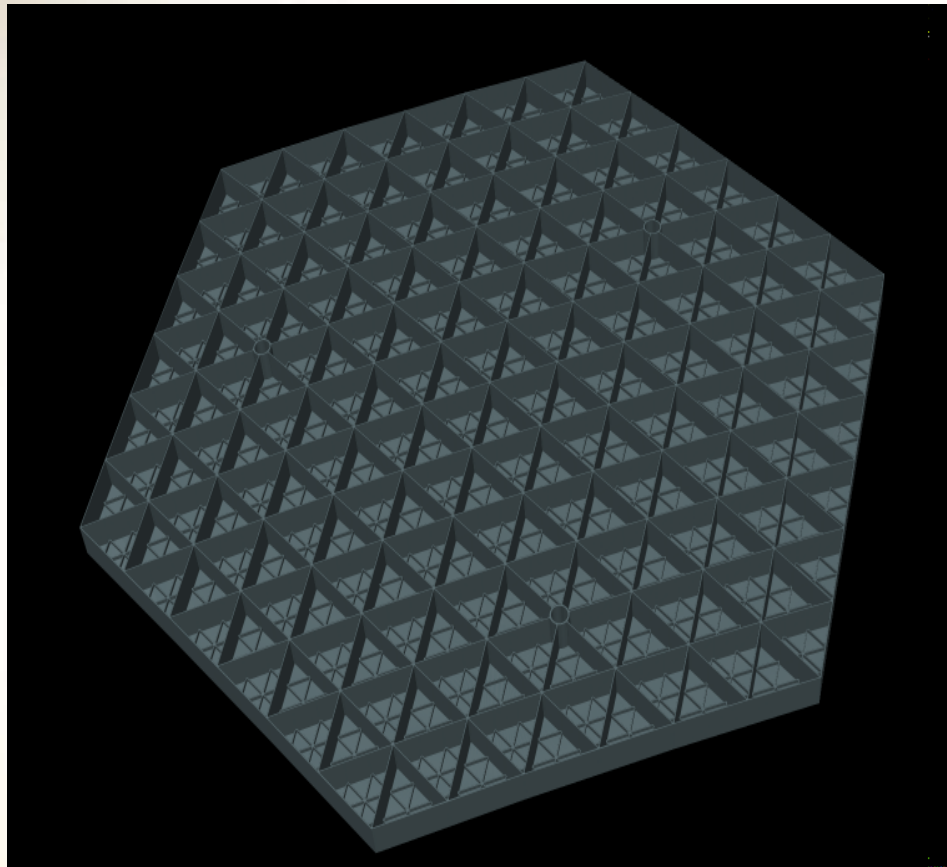
## 1.3 Meter spherical petal outer segment







75 cm spherical hex





75 cm spherical hex – as fired  
~ 11 Kg / m<sup>2</sup> and 700 Hz

